Noise Emission Levels for Vehicles in Ontario

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ABSTRACT

The FHWA traffic noise prediction model (STAMINA) has been adopted in Ontario because of its flexibility and analytical features, which accommodate changed conditions through simple updating procedures. Major inputs for STAMINA are the reference energy mean emission levels of vehicle classes as a function of speed. These functions were established by the FHWA in their original report on the basis of data collected in the United States before 1978. However, conditions in Ontario in 1985 are different, and the noise emission level functions used in the STAMINA and other related programs should be reevaluated. Data on reference emission levels of cars and of medium and heavy trucks were collected during 1984 and 1985, processed, and statistically analyzed. From these data, functions of reference noise emission levels with vehicle speed were established for those vehicle groups. These functions can be used in programs derived from the FHWA model. The findings in Ontario confirm those in other jurisdictions in the United States, namely, that heavy trucks emit less noise at high speeds than originally indicated by the FHWA model. Further, it is shown that about 4 percent of heavy trucks are notoriously noisy compared with the general population and cause an upward shift of the reference emission level function by 0.5 to 1 dBA. These noisy trucks are relatively rare events, which may or may not be missed in noise measurements of short duration (20 min), but they have a high impact on the level of noise pollution.

Numerous methods have been developed to estimate or predict highway traffic noise, a major source of noise pollution in residential areas. In Ontario for many years the standard method of predicting traffic noise adjacent to freeways and highways was that developed by Hajek (1). However, his model was empirically based on numerous field measurements and comprises a mathematical simulation of overall traffic flow noise. Thus, like other empirical models, this method was bound to become outdated as soon as real-world conditions changed. For example, more stringent vehicle emission level standards would reduce noise effectively and invalidate some of the assumptions on which the model was based. Reformulation of such empirical models is rather difficult because one must resort to repetition of numerous field measurements.

In 1977 FHWA developed an analytical model for traffic noise prediction based on and built up from basic principles of acoustics (2). Such a model can easily be calibrated for new conditions because reference noise emission levels from various classes of vehicles are used as separate independent inputs. Once mean values of these levels have been established, the total noise from overall traffic flow is then calculated from the amount and composition of traffic as it exists or is projected for a particular highway. When the FHWA model was published, certain reference noise emission levels were recommended and spelled out as functions of speed and vehicle type (3). At the same time, however, it was recommended that each agency (state or province) carry out its own investigations of noise emission levels of the prevailing classes of vehicles, taking into account regional conditions such as composition and design of truck or automobile populations, enforcement, and compliance with regulations and standards. Furthermore, such conditions may change significantly in the course of time, so that collection and processing of vehicle noise data should be repeated periodically (i.e., every 5 or 10 years).

In other words, once sufficient emission level data have been collected, the analytical character of the FHWA model allows for a relatively simple update of prediction calculations, as described and reported in the following discussion.

In 1984 the state of Georgia reported (4), on the basis of a relatively small sample of measurements, that heavy and medium trucks were emitting less noise at higher speeds than that predicted by the FHWA model (1,2,5). In other words, the FHWA model was overestimating noise levels for traveling near the legal speed limit (80 to 100 km/hr).

In 1985 a California report (6) based on a much larger sample of measurements showed similar findings--trucks at higher speeds are less noisy.

The analytical traffic noise prediction model of the FHWA was introduced in Ontario in 1982 and was finally adopted more for its flexibility than for its superior accuracy. Using the original FHWA emission level functions, the model revealed a tendency for slight overprediction of noise along expressways when predicted and measured values were compared. Thus, it was decided to carry out a specific Ontario study on noise emission levels of vehicles.

The primary objective of the study was to develop and establish up-to-date vehicle noise reference energy mean emission levels for Ontario, as required and defined by the FHWA prediction model (2,6). These reference noise levels are also needed for simplified prediction methods that have been developed from the original FHWA model to serve the less sophisticated needs of, for example, environmental planners (7,8).

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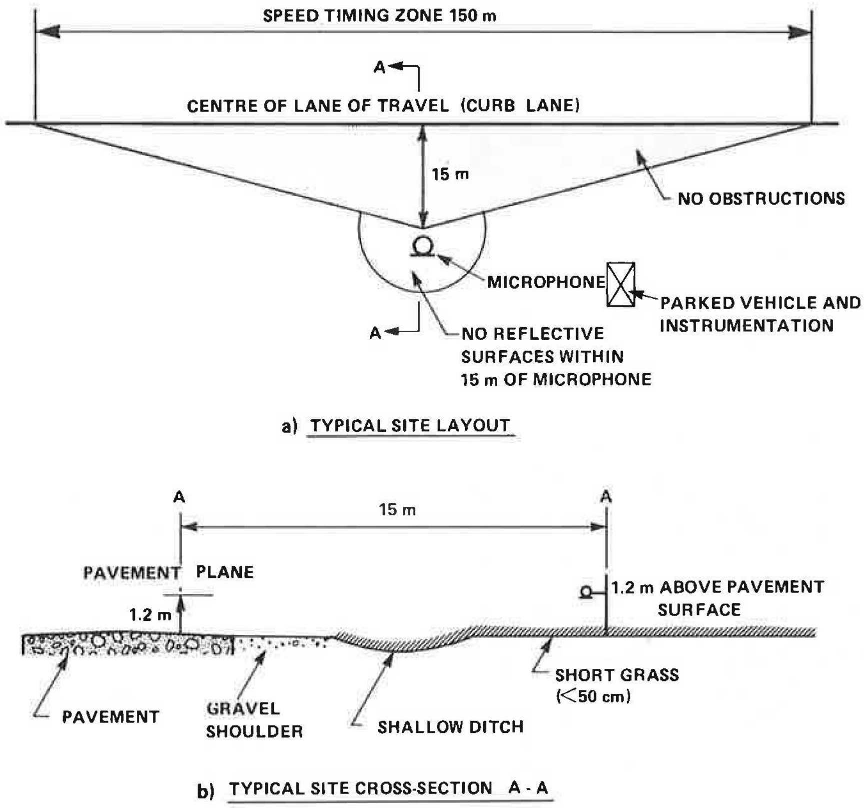


FIGURE 1 Typical layout of roadside measurements.

FIELD MEASUREMENTS

Test Sites

The basic requirements of a test site are shown in Figure 1a and 1b. The sites chosen for inclusion in the Ontario survey and a map showing the location of these sites are presented in Figure 2. The sound level measurement sites are spread over a wide cross section of the Ontario road system.

It was necessary to test a number of sites in order to include representative variation in pavement type, ground condition, vehicle type, and vehicle speed. All sites were located in an open level area free of obstructions such as parked cars, buildings, or sign boards, and all had low peak background sound levels more than 10 dBA below the lowest measured levels. Further, as a result of an investigation at the airport site with vehicles traveling on the runways, it was found to be very important to conduct measurements when the windspeed does not exceed a limit of approximately 20 km/hr.

The microphones at all sites were located 15 m from the center of the traveled lane and 1.2 m above pavement elevation. A clear line of sight was maintained between the microphone position and the roadway in both directions. All pavements were in fair to good condition. In short, measurements were carried out in accordance with the general requirements given by FHWA (9).

All measurement sites were in rural or quiet urban locations with low traffic volumes so that pass-

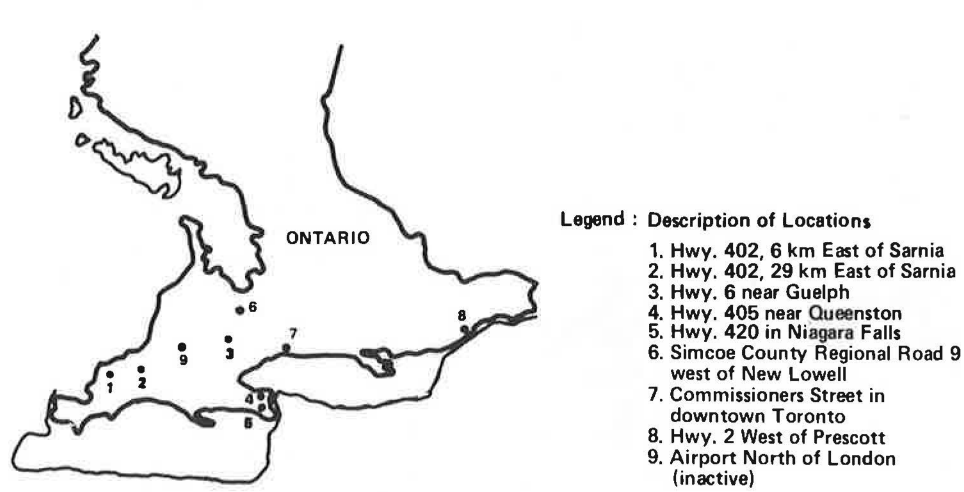


FIGURE 2 Single event (truck) on Highway 402.

FIGURE 3 Instrumentation of roadside measurements.

FIGURE 4 Sites of roadside measurements in Ontario.

ing vehicles could be measured independently, as single events (Figures 3 and 4).

Measurement Procedure

Before field measurements were made, the instruments were checked in the laboratory to ensure proper calibration. The instruments used in this procedure were as follows:

- Bruel and Kjaer (B&K) noise level analyzer, Type 4426
- B&K sound level meter, Type 2218
- B&K calibrator, Type 4230
- B&K alphanumeric printer, Type 2312
- B&K graphic level recorder, Type 2306
- B&K 1/2-in. microphone, Type 4165
- B&K 30-m microphone extension cable, Type AO 0029
- B&K microphone windscreen
- Uher tape recorder, Type 4200 Report Monitor
- Tripod

All of the sound level meters complied with the requirements for Type 1 precision instruments of the American National Standards Institute (ANSI S1.4, 1983).

Two sound level measurement systems were set up and calibrated on site with microphones placed at the same location, 15 m from the highway. The main reason for using two independent measuring systems is that one system can act as a check on the other, thus helping to avoid the possibility of introducing any gross errors in the measured sound levels. After initial calibration, a 10-min comparison test of the performance of the sound-measuring instruments using the noise emitted from the traffic on the nearby highway was done. The measuring systems were recalibrated approximately once every hour or sooner when necessary (for example, when batteries had to be changed in an instrument). The two measuring systems were constituted as follows.

System 1 consisted of a microphone and preamplifier placed on the end of a 30-m extension cable and connected to a B&K 2218 sound level meter. The AC voltage output from this meter was tape recorded on one channel of a stereo tape recorder and the other channel was reserved for comments about the vehicle passing by. The sound level meter in this system was not used to read the sound levels as the vehicle passed but only to condition the signal for tape recording. The recorded audio tapes were kept for evaluation at a later date in the laboratory.

System 2 comprised a microphone and preamplifier placed on a 30-m extension cable and connected to a B&K 4426 noise level analyzer. This system allowed for direct field evaluation of the sounds emitted from passing vehicles.

The maximum sound level measured as the vehicle passed was obtained from the noise analyzer in System 2. This, as well as the speed and type of vehicle, were recorded on data sheets in the field. The speed of the vehicle was measured by timing it over a 150-m (see Figure 1) distance. These data were later verified from information recorded on the audio tapes of System 1.

RESULTS

Data on vehicle noise emission levels were collected at various locations in Ontario, as shown in Figure 2, to obtain a representative set of pooled vehicle- and speed-related data for Ontario conditions. These data were processed in two ways with respect to groupings or classes of vehicles with similar levels of noise emission.

First, in accordance with the original FHWA report (1), vehicles were assigned to one of three classifications--heavy trucks (HT), medium trucks (MT), and automobiles (A), which includes other vehicles of similar noise emission. An accurate definition of these classes is given in the FHWA report (1,p.4).

Second, vehicles were further classified in accordance with groupings customary in Ontario, namely, by dividing them into long trucks (LT), short trucks (ST), and automobiles (A). These vehicle classes were introduced, not for acoustical reasons but because traffic data can be more readily obtained in these terms. The Ontario classes are shown in Figure 5, and a comparison between the Ontario and FHWA groupings of vehicles is given in Figure 6.

The measurements were sorted by speed classes (every 5 km/hr) as well as by vehicle type, and each group or cluster of measurements was statistically analyzed. The results are shown in Table 1, in which vehicles are classified according to the FHWA definitions (HT, MT, and A). The sample size for each speed and vehicle class is also shown, together with the mean and standard deviation of noise emission levels. The results for the second grouping by Ontario vehicle classes (LT, ST, and A) are similar and are therefore not shown in tabular form.

The data shown in Table 1 were subjected to a linear regression analysis in order to obtain the customary expressions for the reference energy mean noise emission levels of each vehicle class. The resulting curves are presented in Figures 7 and 8 for the FHWA and Ontario classes, respectively.

In Figure 9 the Ontario emission levels are compared with the originally published FHWA levels (1) (HT, MT, and A). The comparison shows that in Ontario trucks emit less noise at high speeds. On the other hand, automobiles are noisier, especially at lower speeds. Furthermore, medium-weight trucks are somewhat less noisy at higher speeds but slightly noisier at lower speeds. Since speeds of 80 to 100 km/hr are legal in Ontario, the aforementioned difference must lead to an overprediction of truck noise when the original FHWA emission level functions are used. The difference in car noise at high speeds is less significant.

Figure 10a, b, and c gives the statistical variations of the measurements and average values of emission levels in each speed class and vehicle

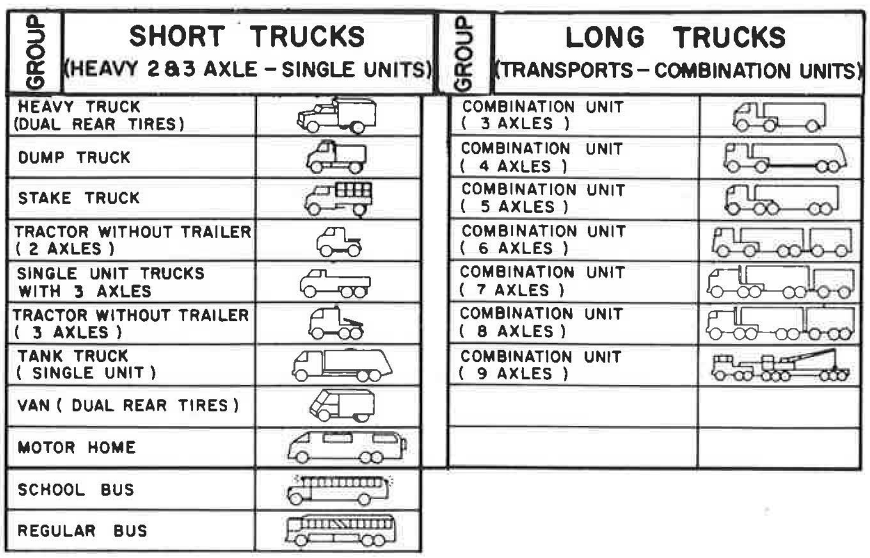


FIGURE 5 Short-truck–long-truck classification in Ontario.

	MTC SHORT TRUCKS SINGLE UNITS		MTC LONG TRUCKS COMBINATION UNITS
	MEDIUM TRUCKS	HEAVY TRUCKS	
AXLES	2 AXLES - 2 TIRES ON REAR AXLE	2, 3 & 4 AXLES - 4 TIRES ON REAR AXLE/S	3 OR MORE AXLES TRANSPORTS
WEIGHT	GENERALLY LESS THAN 5 500 kg	MAX. 38 300 kg	MAX. 63 500 kg
LENGTH		MAX. 12.5 m	MAX. 21 m
BODY STYLES	VANS, PICKUP	DUMP, STAKE, TANKER, BOX, TOW TRUCK	TRACTOR TRAILERS, FLATBED, TANKER TRAILERS, CAR CARRIERS

FIGURE 6 Comparison of classifications, Ontario and FHWA.

TABLE 1 Results of Field Measurements

	Speed Class	Noise Emission Level: Mean	Noise Emission Level: Standard Deviation	Sample Size
HT	40	79.2	2.9	15
	50	83.0	3.3	33
	60	82.8	2.4	35
	65	83.9	2.2	34
	70	84.7	2.7	52
	75	85.0	2.7	78
	80	83.9	2.2	106
	85	84.4	2.3	133
	90	84.9	2.4	119
	95	85.7	2.2	122
	100	85.9	2.4	88
	105	86.1	2.5	41
	110	85.9	1.8	29
Total				885
MT	50	75.2	4.0	19
	60	79.2	4.3	10
	70	77.7	3.3	15
	75	81.0	3.9	21
	80	80.0	3.5	29
	85	81.4	3.0	25
	90	82.5	3.9	35
	95	82.2	2.9	19
	100	83.0	3.9	15
	105	84.3	3.9	7
Total				195
A	50	64.5	2.3	10
	55	65.2	2.1	7
	60	67.9	1.9	13
	65	68.0	1.8	12
	70	70.9	2.2	30
	75	71.8	2.2	55
	80	72.4	2.2	100
	85	73.2	2.1	91
	90	73.0	2.1	138
	95	73.9	2.2	117
	100	73.9	1.5	112
	105	74.7	1.8	52
	110	75.0	1.7	60
	115	75.8	1.9	20
	120	76.7	1.4	6
	130	77.5	1.8	7
Total				830

Note: HT = heavy truck, MT = medium truck, A = automobile. Data are for all sites, pooled.

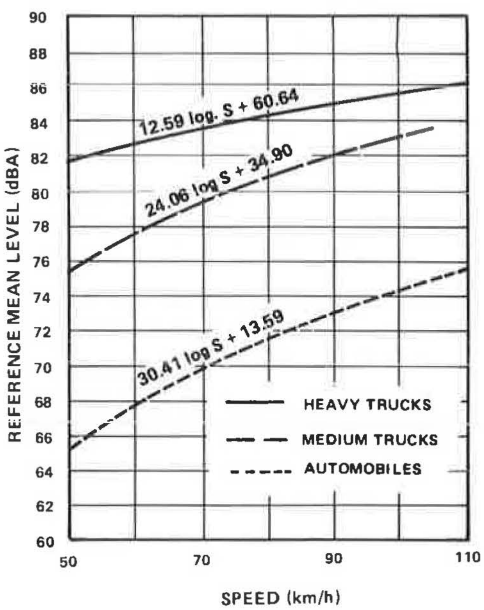


FIGURE 7 Emission levels of Ontario vehicles classified according to FHWA.

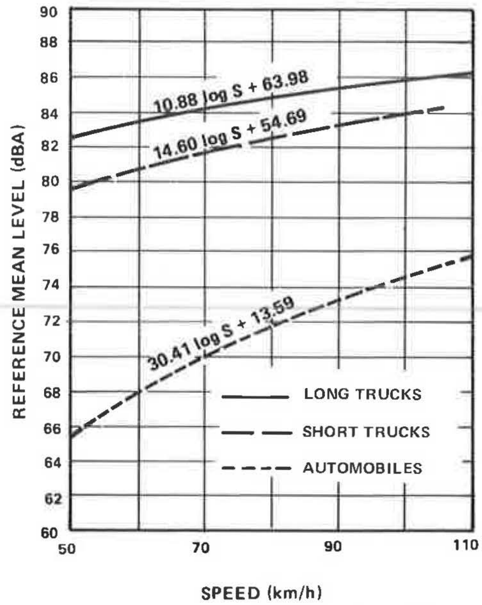


FIGURE 8 Emission levels of Ontario vehicles classified according to short trucks versus long trucks.

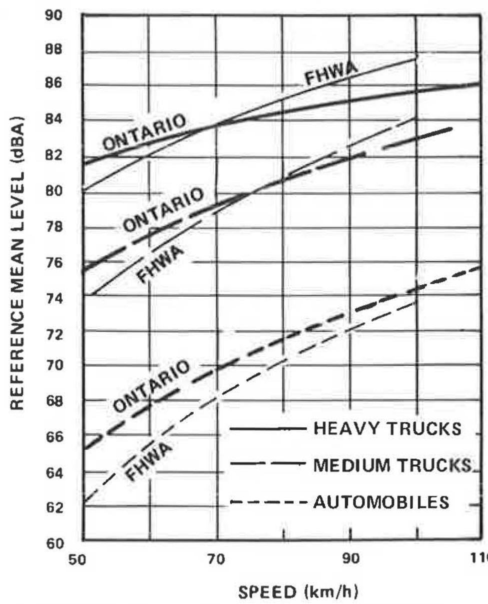


FIGURE 9 Comparison of Figure 7 emission levels with original FHWA levels (*1*).

group. The points of plus or minus one standard deviation (vertically) are also plotted. The vehicle groups used in Figure 10 are those defined by FHWA. The curves shown are regression lines identical to those in Figure 7.

The resulting equations for the reference energy emission levels as found from the 1984-1985 measurements in Ontario are listed in Table 2. This table can be used to provide new, up-to-date input for the various programs based on the FHWA model (1,5,8) when they are used in Ontario.

The effect of the new equations for Ontario is shown by a typical case (Figure 11), for vehicles traveling close to the legal speed limit of 100 km/hr. This example of an expressway in an urban

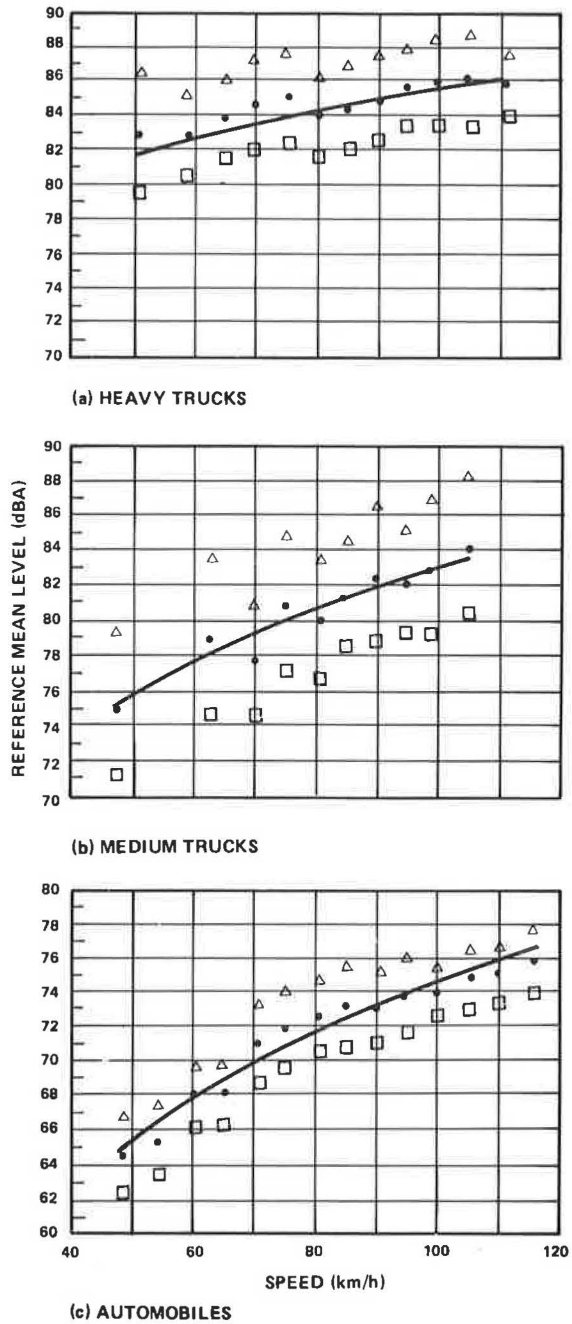


FIGURE 10 Standard deviations of emission level curves.

TABLE 2 Reference Mean Emission Levels in Ontario

Vehicle Class	Equation
Heavy trucks	12.59 logS + 60.64
Long trucks	10.88 logS + 63.98
Medium trucks	24.06 logS + 34.90
Short trucks	14.60 logS + 54.69
Cars	30.41 logS + 13.59

Note: S = speed (km/hr).

area consists of three westbound (R1) and three eastbound (R2) lanes. Predictions at 30 m and at 60 m from the near-lane center are compared. In both cases, the original FHWA equations predict noise 1 dBA above that predicted by the new Ontario equations. For lower speeds the difference will be smaller or will be reversed. For a larger percentage of trucks at 100 km/hr, the difference would be larger than 1 dBA.

DISCUSSION OF RESULTS

Statistical Problems

Single-event noise emission levels of vehicles were measured in terms of adjusted decibels, which is a logarithmic scale; therefore, the measured values must be converted to sound pressure energies before they are manipulated. The mean values of each sample in each speed and vehicle class were calculated as follows:

$$L_m = 10 \log \left[(1/n) \sum_{i=1}^{n} 10^{L_i/10} \right] \quad (1)$$

where

L_i = noise emission level of a single event (dBA),
L_m = mean value of sample, average noise emission level (dBA), and
n = sample size.

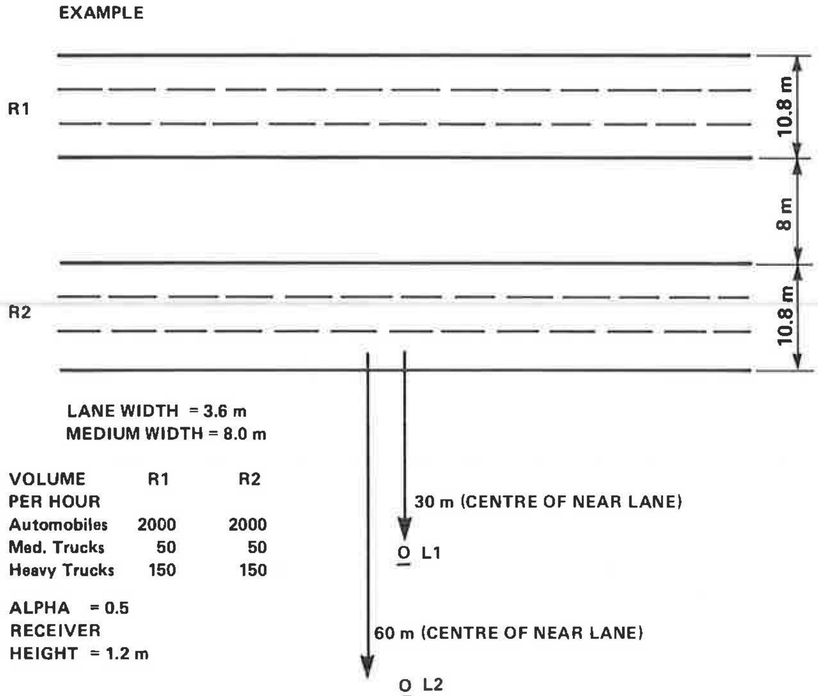
This method of calculating average values of noise emission levels is consistent with the definition of L_{eq}.

The normalized distribution of sound pressure energy for the Ontario heavy-truck population is shown in Figure 12. To obtain this distribution, the sample data from all heavy trucks traveling at speeds greater than 80 km/hr were normalized to a zero mean value in each speed group and then pooled. The pooling was possible because F-tests showed no statistically significant difference between the standard deviations of the different speed groups. Whereas Figure 12 shows the distribution of sound pressure energy measurements on a nonlogarithmic scale, Figure 13 gives the same information as normalized noise emission levels in terms of adjusted decibels, which is a logarithmic scale.

Both Figures 12 and 13 exhibit a long tail of high noise emission levels. The upper part of the tail, beyond 5 dBA above the mean value, represents only approximately 4 percent of the truck population, which contributes an additional 1/2 to 1 dBA to the average emission level of trucks. This represents about one-fifth of the sound pressure energy.

This 4 percent of unusually noisy trucks is intrusive in its noise impact compared with the general population, and from the shape of the distribution curves one may conclude that this may be due to unusual circumstances, such as faulty mufflers. More stringent enforcement of regulatory standards could discourage such high emission levels and would affect only 4 percent of the truck population.

With regard to the practice of noise measurements, the following should be pointed out. In a small sample size (such as that obtained by 20 min of measurement on roads of low traffic volume), those very noisy vehicles in the tail of the distribution curves will probably be missed. This would result in a lower average value of noise than would be representative for a 24-hr L_{eq}, the current Ontario standard of noise control. With the increasing sample size the measured average noise emission level would slowly increase because of the increasing probability of encountering those excessively noisy events from the tail of the distribution. Thus, measurements of 20 min duration at low traffic volumes may underestimate the 24-hr L_{eq} noise that is used as a standard duration of measurement in Ontario.



RESULTS	FHWA DATA (dBA)	ONTARIO DATA (dBA)	DIFF. (dBA)
L1	73.9	73.0	0.9
L2	70.1	69.3	0.8

FIGURE 11 Comparison of effect of new Ontario vehicle noise emission levels with that of original FHWA levels.

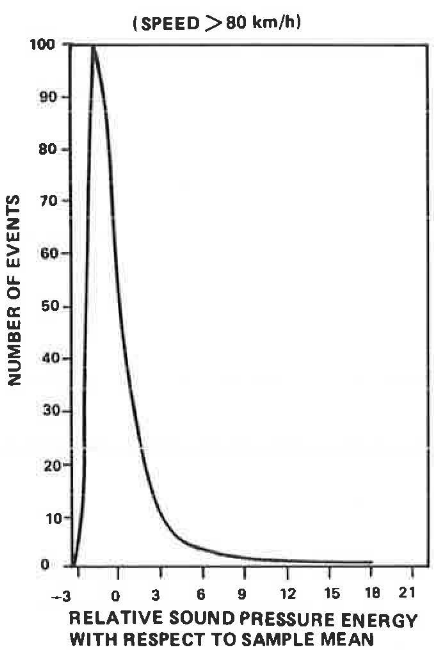


FIGURE 12 Heavy-truck noise distribution: energy.

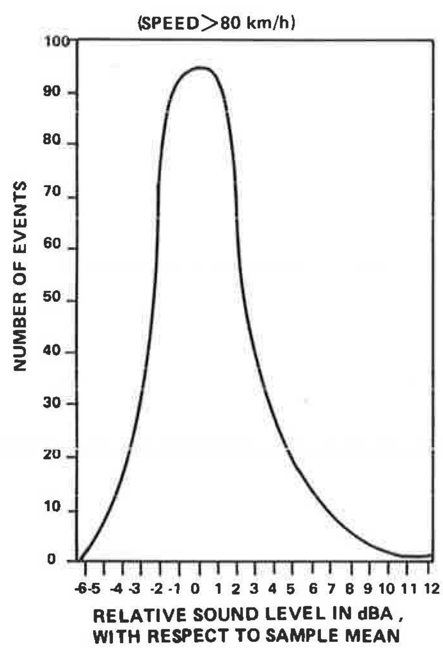


FIGURE 13 Heavy-truck noise distribution: adjusted decibels.

CONCLUSIONS AND RECOMMENDATIONS

Functions of reference energy mean emission levels with speed have been established for heavy trucks, medium trucks, and automobiles in Ontario. The levels are different from those currently used in the STAMINA program of the FHWA model. In particular, it has been found that heavy trucks are less noisy at high speeds, near the legal speed limit. Trucks and cars at low speed are noisier.

When using STAMINA or any other noise prediction program derived from the analytical FHWA model, new equations for reference emission levels should be used. For Ontario, these are as listed in Table 2.

Noise emission levels of vehicles should be regulated by establishing a legal maximum noise limit to exclude the rare events in the upper tail of vehicle noise distributions that have a high impact on noise pollution.

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